# Low Impact Development Strategies

## Infrastructure for Sustainable Communities

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WHS ETSD SEMB

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# Report Documentation Page

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**Standard Form 298 (Rev. 8-98)**
Prescribed by ANSI Std Z39-18

# Today's talk covers…

- Natural Systems, Engineered Systems, Potential Impacts of Development
- LID overview: goal of these sustainable practices, and strategies
- LID materials, methods, systems and technologies, and Case Studies
- Costs & Benefits
- Policies
- Resources

# Ecosystems and society

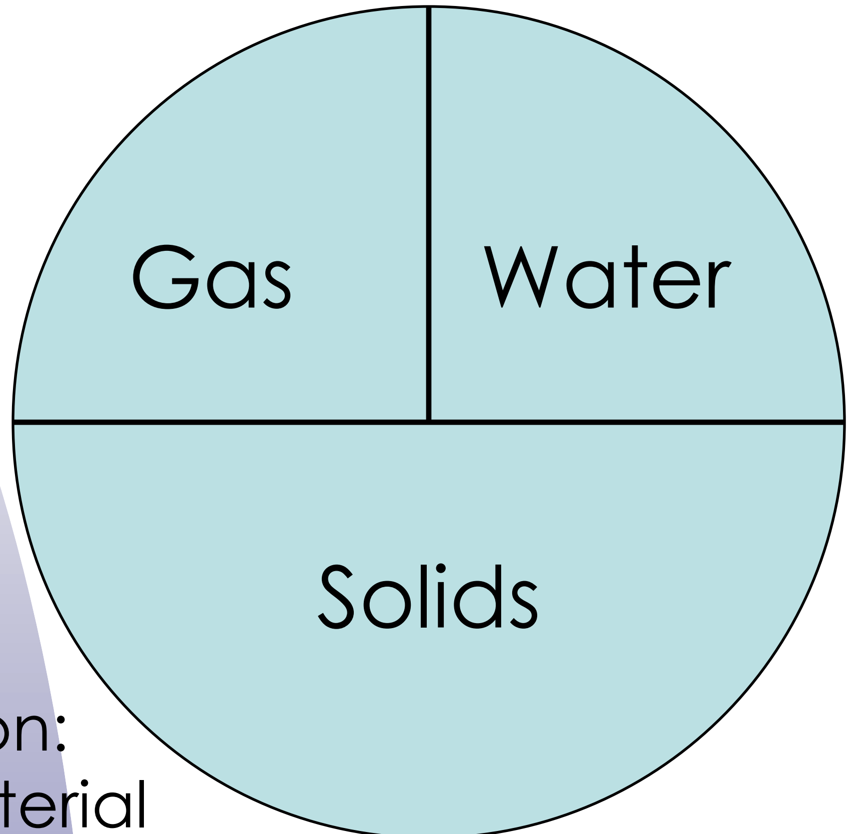
In urban, suburban, and rural communities, structures / infrastructure serve -

- Government
- Commerce
- Recreation areas
- Industry
- Schools
- Residences

Society relies upon both Natural and Engineered systems for -

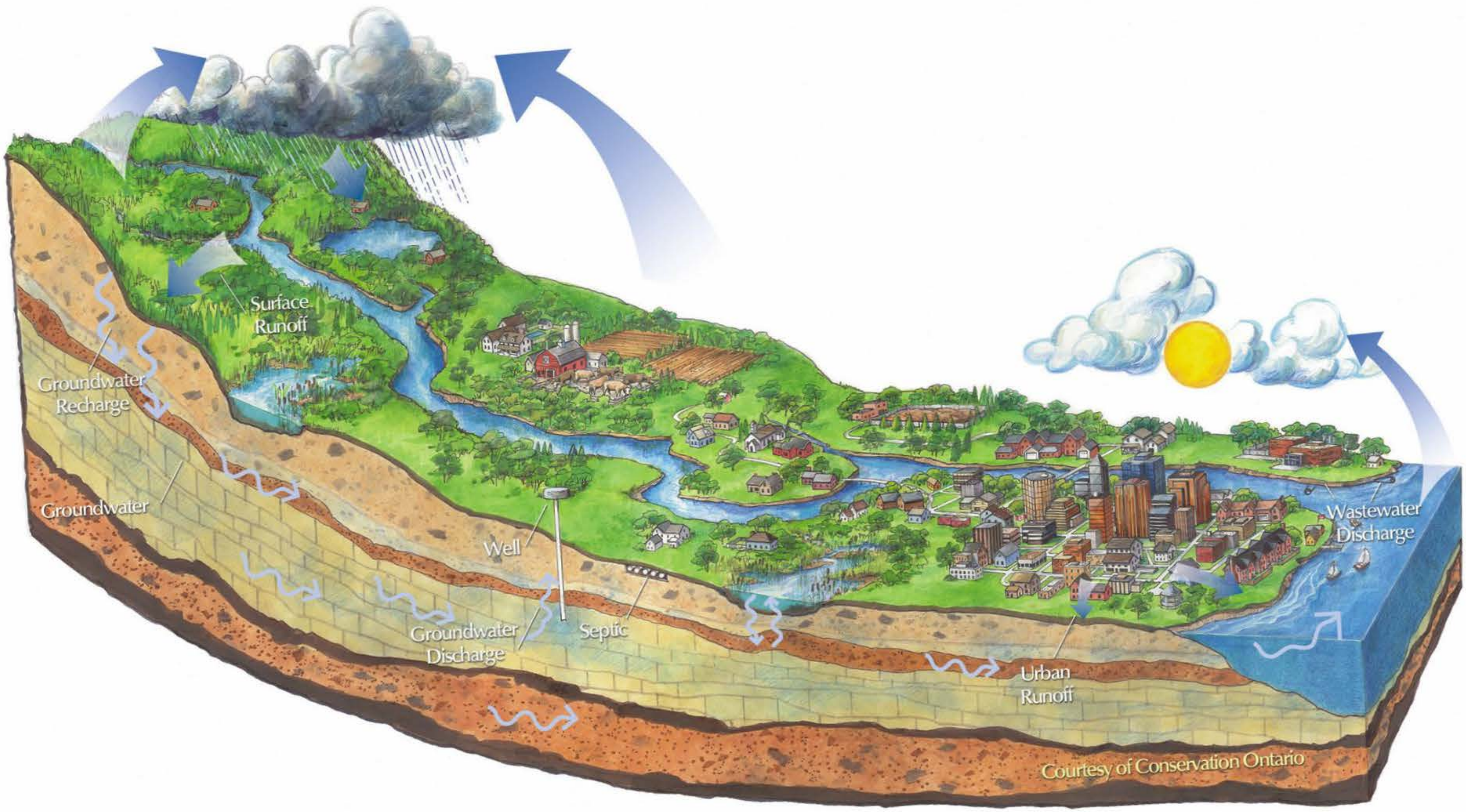
- energy
- air, water, food
- moderate temperatures
- earth resources, and
- contact with nature

# What is soil?

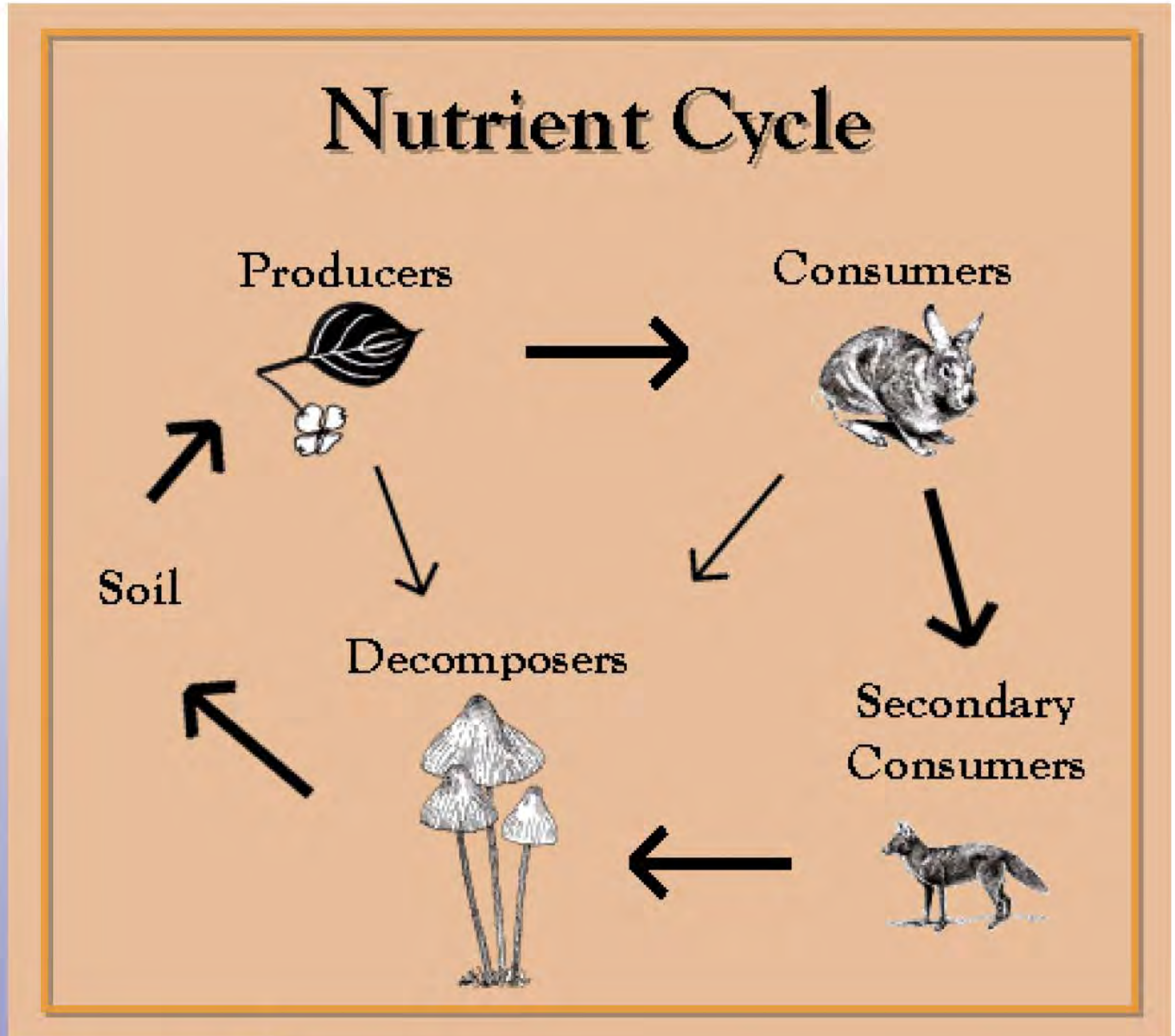



Soil's composition:
- 50% solid material
- 25% water
- 25% gas

# The water cycle



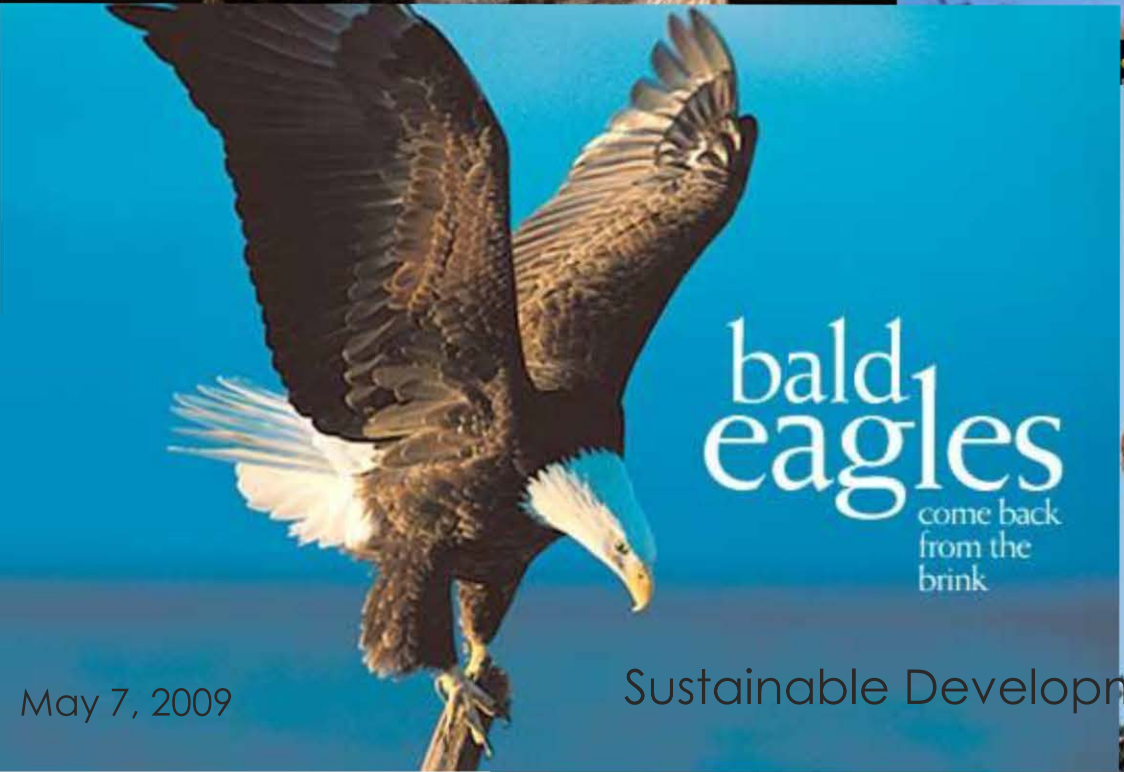
# The Nutrient Cycle



# U.S. Migratory Shorebirds

# Raptors

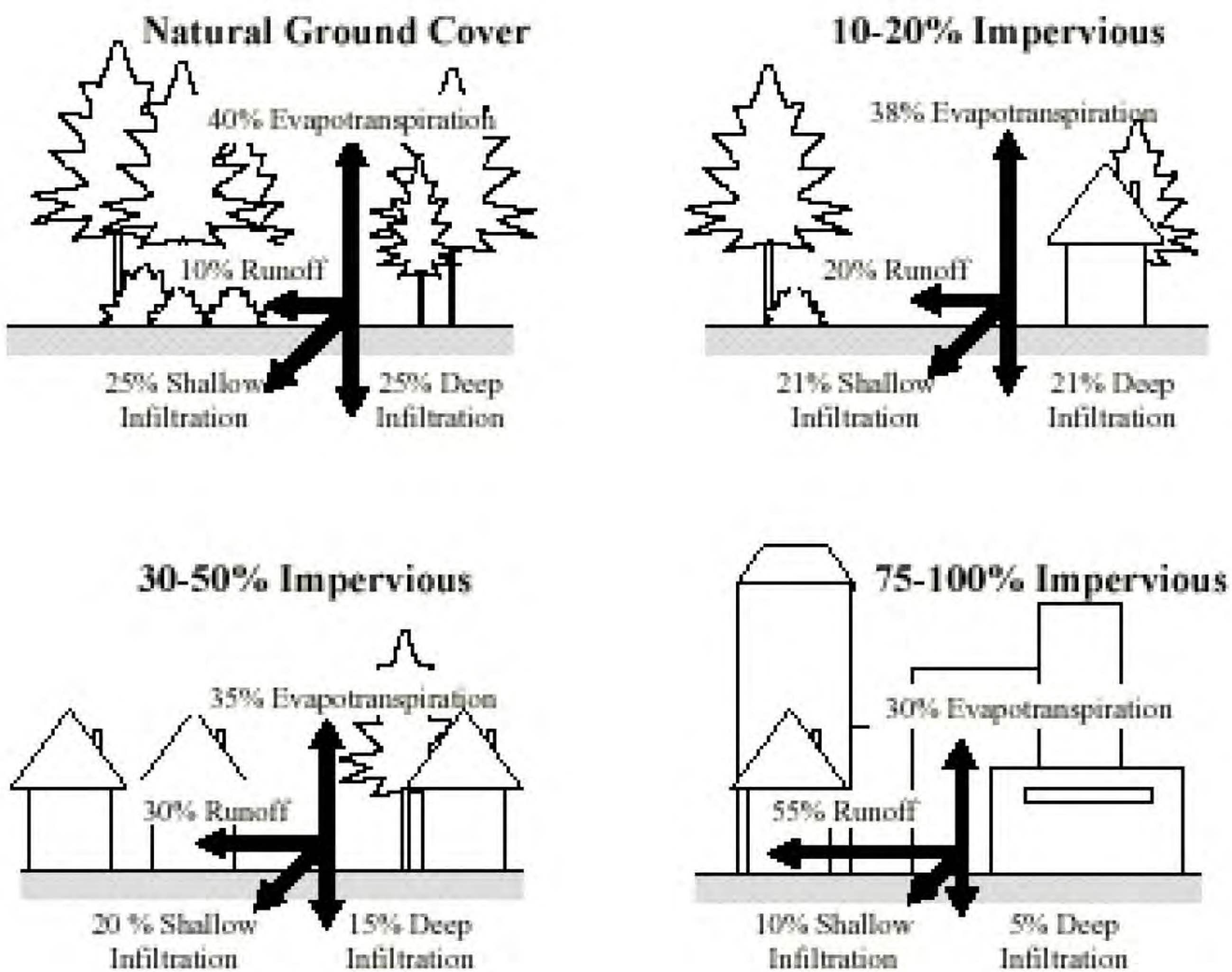

re wallpapers at www.nationalgeographic.com
Photograph by Rich Reid


bald eagles
come back from the brink

# Mammals – Washington DC region

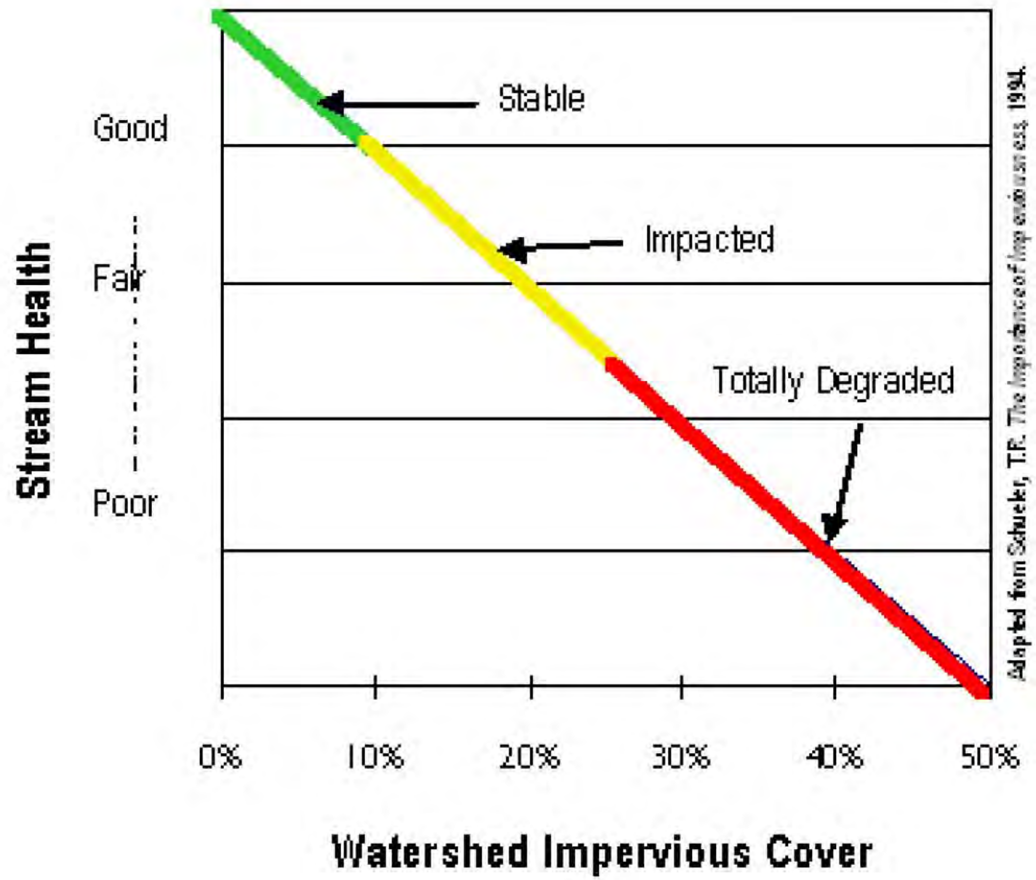
# Land Development components

- Groundwater conditions / soil stability
  To maintain structural integrity,
  primary principle: keep water out of buildings
- Water systems serving buildings – rivers and streams, water treatment
- Agriculture – water affects land, agricultural processes affects land
- Roads – mobility and severe weather
- Electrical power lines, and
- Communication:
  Telephone and internet lines.




Source: Adapted from Arnold and Gibbons, 1996

# Relationship between Impervious Cover and Stream Health



# Impervious cover in Arlington VA

Arlington's
Impervious cover
~ 40%

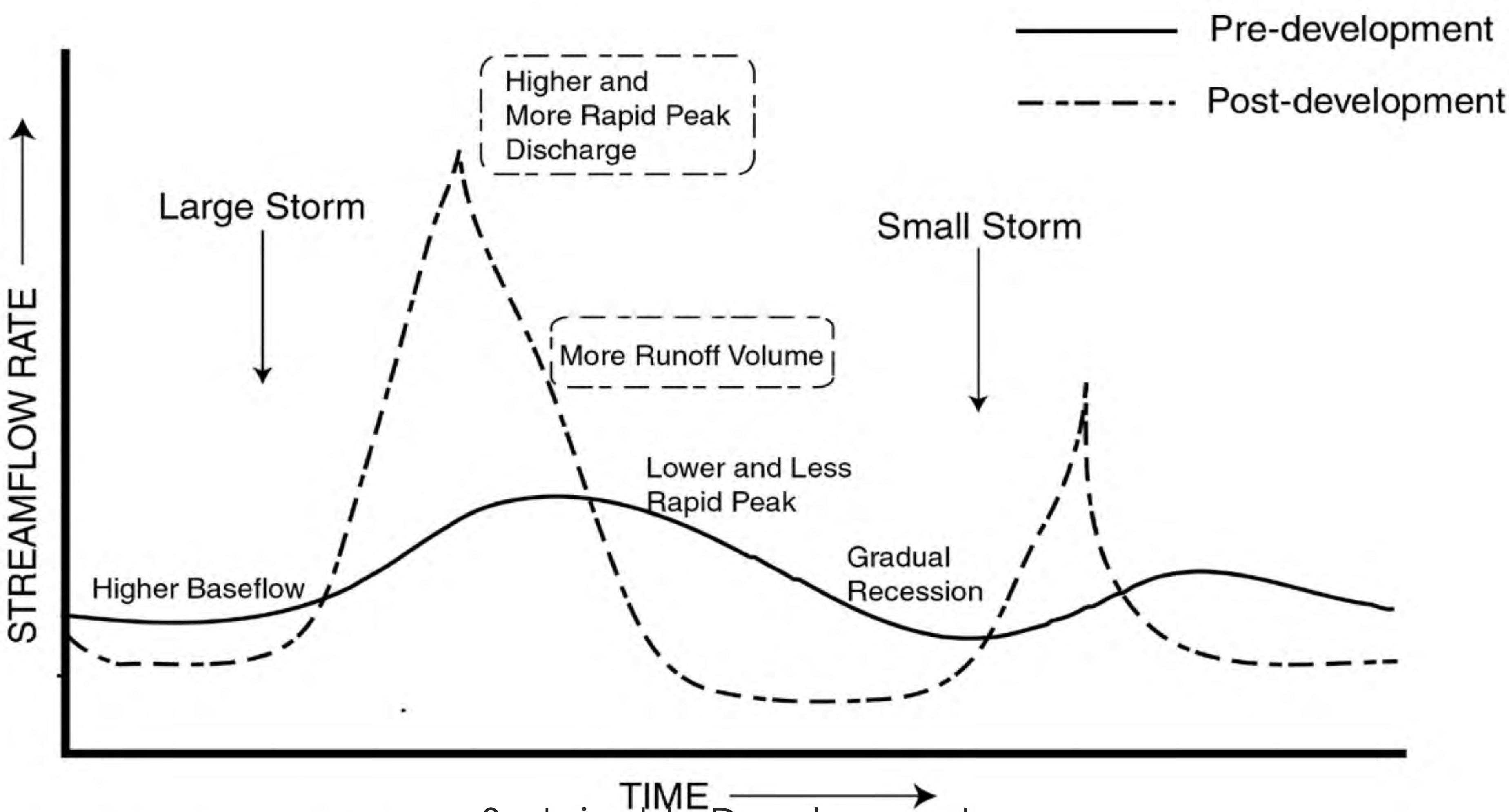
# Arlington VA
# storm sewer network

# watershed managers deal with holistic effects...

# What's the Problem?

Source: EPA Office of Water, 2008

# Post-development Feast or Famine




Changes in stream hydrology as a result of urbanization (Schueler, 1992).

# Healthy Watershed

In watersheds with 5% impervious cover or less, streams remain stable and connected to floodplains –
-maintains good pool and riffle structure
-large, wetted perimeter in low flow times
-good riparian canopy coverage.

# 5% to10% Imperviousness


This stream shows signs of stress –

- bank undercutting

- exposed tree roots,

- significantly eroded river banks,

- streambed is sedimented

# 10% Imperviousness

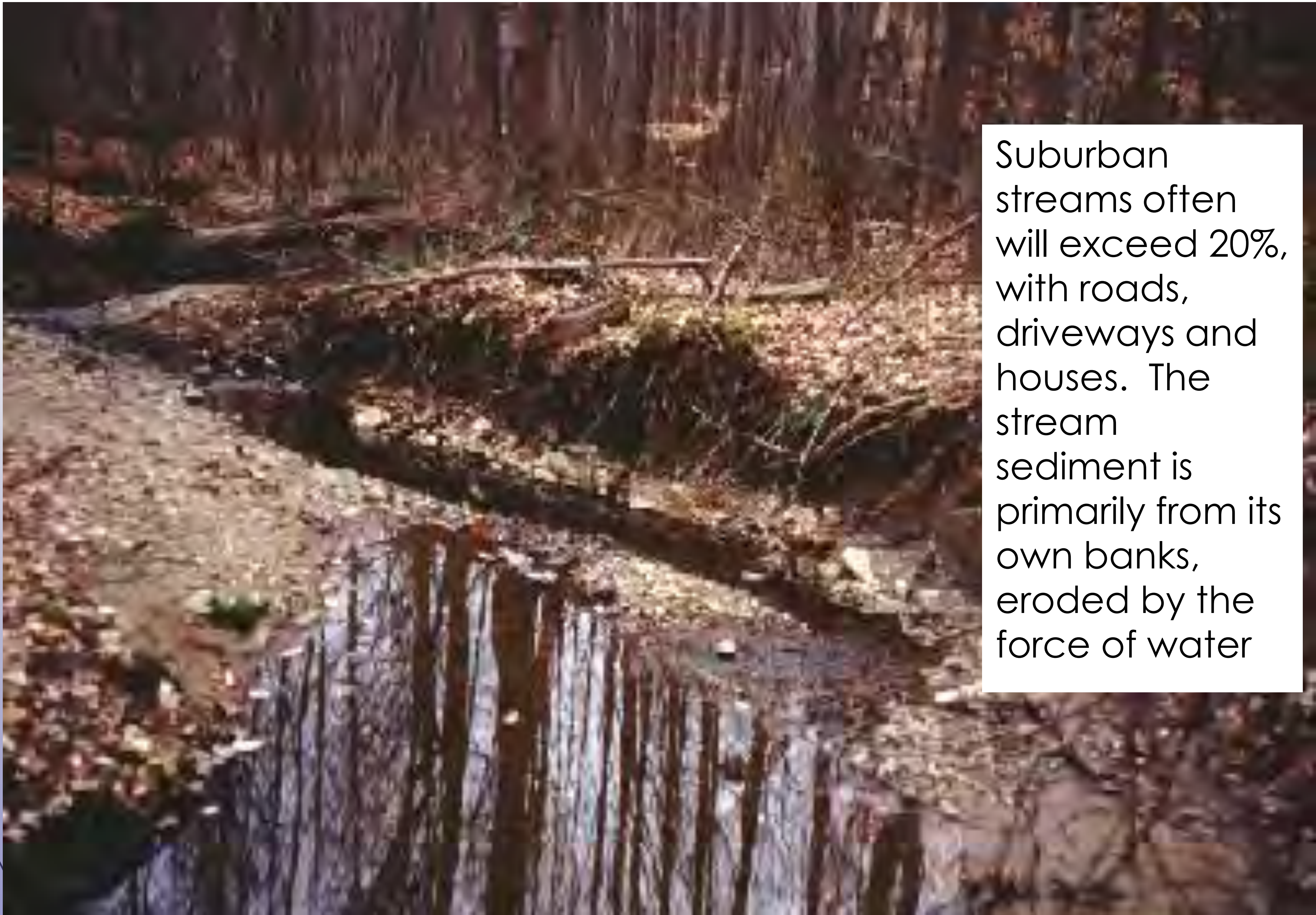
At 10% impervious cover, the stream has more visibly impacts –

-approximately double original size

-Exposed tree roots are

-Lost the pool and riffle structure belonging to sensitive streams

# 20% Imperviousness



Suburban streams often will exceed 20%, with roads, driveways and houses. The stream sediment is primarily from its own banks, eroded by the force of water

# Also 20% Imperviousness

The surrounding area of this stream is approximately 20% impervious cover. The stream shows erosion that is worsened, due to an absence of vegetation to hold together bank structure.


What needs to change?

# Paradigm Shift: Rain is a Resource

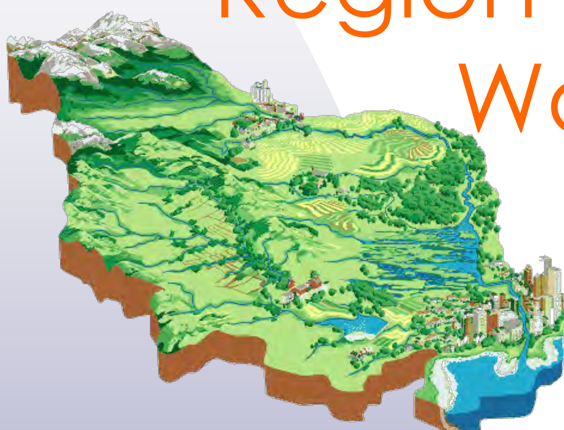
- Drinking water
- Ground water recharge
- Stream baseflow
- Trees & other plants
- Aesthetic qualities

Source: EPA Office of Water, 2008

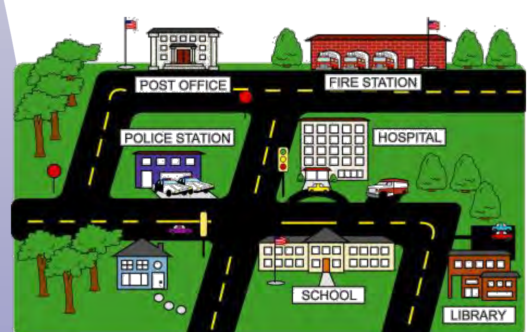
# Paradigm Shift:

## Trifocal Approach to Stormwater Management

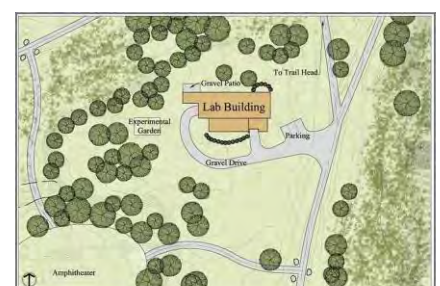
Region or Watershed



Neighborhood




Site







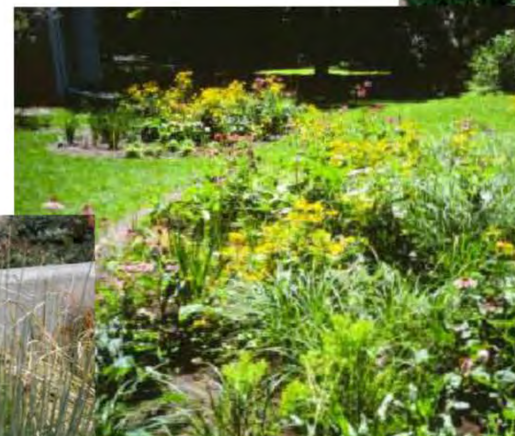



Source: EPA Office of Water, 2008

# Keep Water out of Pipes

Source: EPA Office of Water, 2008

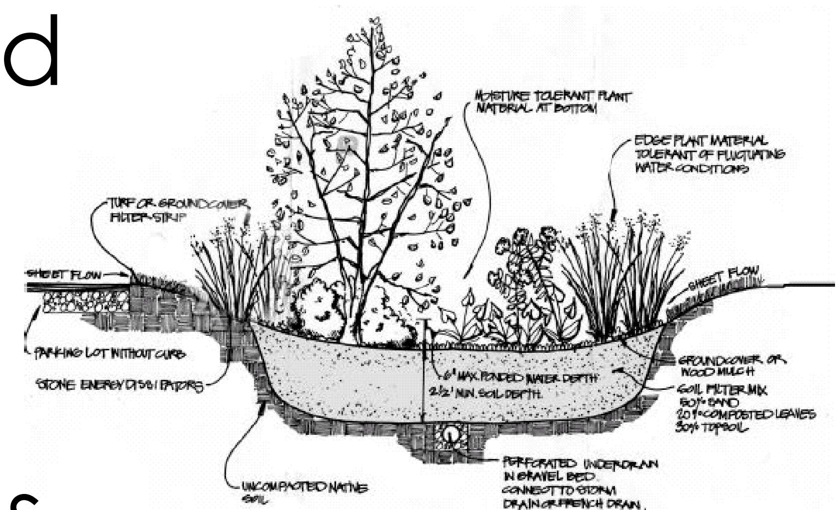
# Bioretention



Source: EPA Office of Water, 2008

# Bioretention

- Soil and plant-based
- Used to filter and infiltrate runoff
- Mimics the natural vegetation's infiltrative properties
- Reduces runoff rates and volumes
- Reduce CSO/SSO volume and frequency






Source: EPA Office of Water, 2008

# Comparison - Removal Efficiencies for Detention and Biofiltration

| Parameter | Dry Detention Basins | Biofiltration Basins |
|---|---|---|
| TSS | 70% - 90% | 90% |
| TP | 10% - 60% | 70% - 83% |
| TKN | 20% - 60% | 68% - 80% |
| BOD | 30% - 40% | 60% - 80% |
| Lead | 20% - 60% | 93% - 98% |
| Zinc | 40% - 60% | 93% - 98% |
| TPHC | 60% - 77% | 90% |



Source: EPA Office of Water, 2008

# Open Swales

Source: EPA Office of Water, 2008

# Grassed Swale Pollutant Removal Efficiencies

| Removal Efficiencies (% Removal) | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Study** | **TSS** | **TP** | **TN** | **$NO_3$** | **Metals** | **Bacteria** | **Type** |
| Caltrans 2002 | 77 | 8 | 67 | 66 | 83-90 | -33 | dry swales |
| Goldberg 1993 | 67.8 | 4.5 | - | 31.4 | 42–62 | -100 | grassed channel |
| Seattle Metro and Washington Department of Ecology 1992 | 60 | 45 | - | -25 | 2–16 | -25 | grassed channel |
| Seattle Metro and Washington Department of Ecology, 1992 | 83 | 29 | - | -25 | 46–73 | -25 | grassed channel |
| Wang et al., 1981 | 80 | - | - | - | 70–80 | - | dry swale |
| Dorman et al., 1989 | 98 | 18 | - | 45 | 37–81 | - | dry swale |
| Harper, 1988 | 87 | 83 | 84 | 80 | 88–90 | - | dry swale |
| Kercher et al., 1983 | 99 | 99 | 99 | 99 | 99 | - | dry swale |
| Harper, 1988. | 81 | 17 | 40 | 52 | 37–69 | - | wet swale |
| Koon, 1995 | 67 | 39 | - | 9 | -35 to 6 | - | wet swale |



California BMP Handbook, 2003

# Parking Lot Island Infiltration Areas

Source: EPA Office of Water, 2008

# Rain Gardens







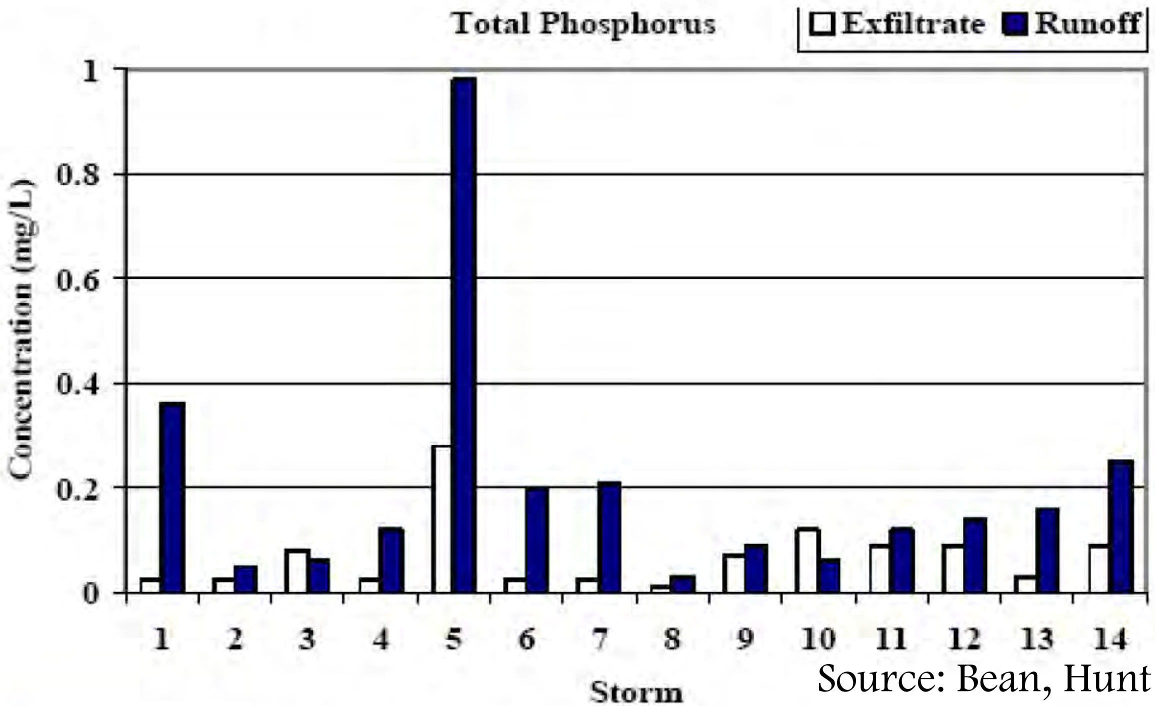
Source: EPA Office of Water, 2008

# Permeable and Porous Pavements

Source: EPA Office of Water, 2008

# Infiltration of Permeable Pavements

| Date | Rainfall Totals (cm) | Volume Attenuation % | Peak Attenuation % | Delay to Peak (hrs) |
|---|---|---|---|---|
| 7/22/2004 | 1.5 | 88 | 81 | 1.3 |
| 7/29/2004 | 1.6 | 53 | 44 | 1.5 |
| 8/5/2004 | 1.7 | 57 | 75 | 1.1 |
| **Mean** | **1.6** | **66** | **67** | **1.3** |




Source: Bean, Hunt & Bidelspach, 2005


Porous
Asphalt
Standard
Asphalt
Source: EPA Office of Water, 2008

# Pervious Pavers: concrete blocks or grids

- Turfstone and Eco-Stone: Virtually all precip. infiltrated over 6 years; another study showed 72% reduction for Eco-Stone (Dietz 2007).
- Unilock pavers: No surface runoff for events measured up to 1 ¼"/hr.
- Plastic Grids: Virtually no runoff from 2 products.

Source: EPA Office of Water, 20

*Runoff quantity and quality from driveways were monitored from water exiting slot drains.*

# Green Roofs

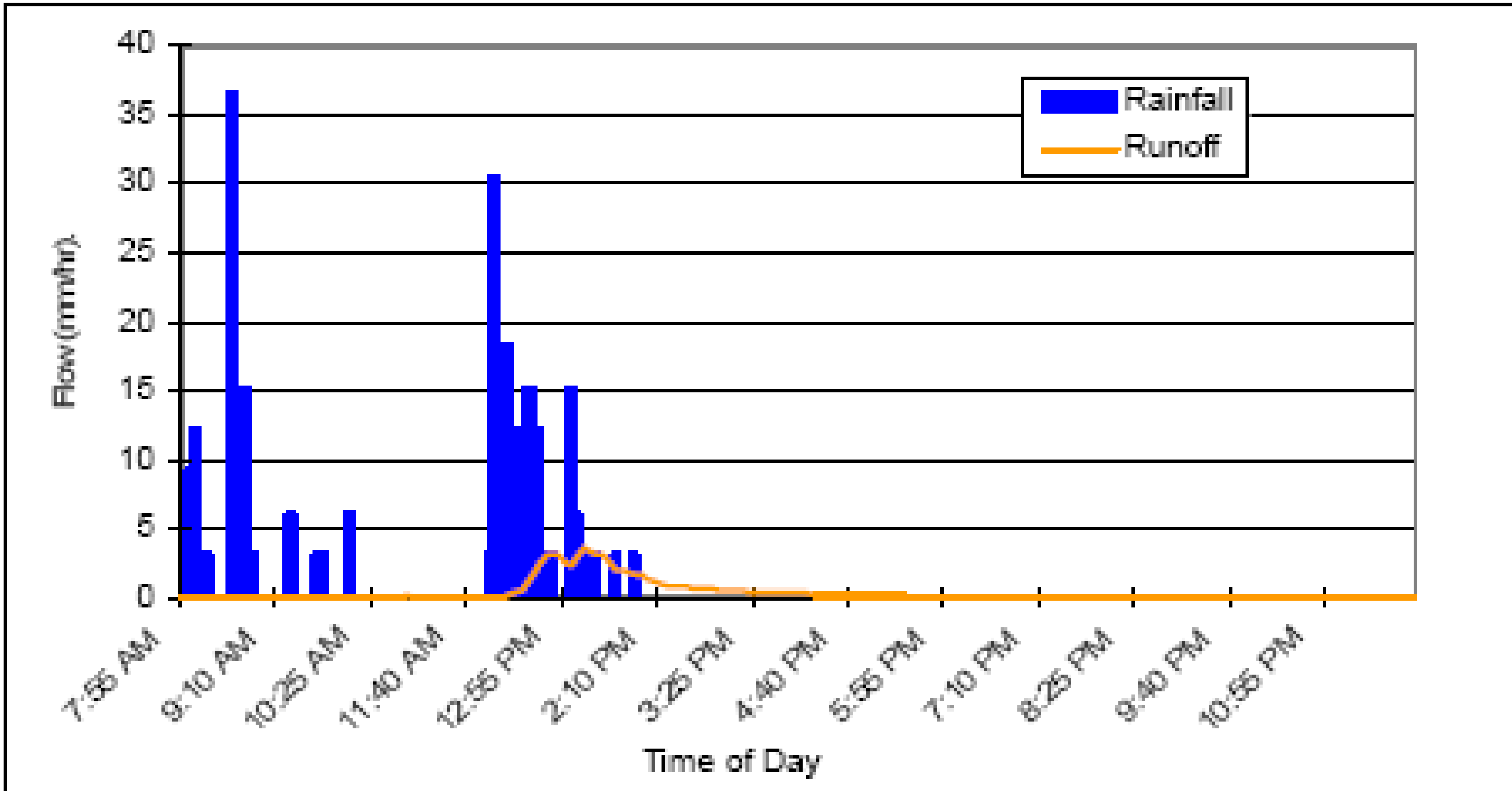






Source: EPA Office of Water, 2008

# Peak Flow Reduction of Green Roof Runoff




Moran, Hunt & Smith, 2005

# Soil Amendment & Structuring

Source: EPA Office of Water, 2008

# Planters








Source: EPA Office of Water, 2008

# Rainwater Harvesting & Use

# Infill Development

- Sites already served by transportation and infrastructure

- Couple with site design practices such as green roofs to effectively manage stormwater



Source: EPA Office of Water, 2008

# Innovative Parking

- Parking structures use less land;
- Reduce number of spaces, reduce perviousness:
  - Share parking
  - Use parking lifts
  - Use unpaved overflow lots



Source: EPA Office of Water, 2008

# Street Design

- Connectivity to reduce car trip lengths
- Multiple modes of transportation
- Narrower roads/ less pavement
- Sidewalks to facilitate more walking


Source: EPA Office of Water, 2008

# Tree & Canopy Programs

- Trees intercept, and evapotranspire significant amounts of water

- Trees filter pollutants
- Canopies shade and cool paved surfaces



Source: EPA Office of Water, 2008

# Water Conservation

- High efficiency fixtures
  and appliances, e.g.,low-flow toilets,
  urinals, showerheads, faucets;
- Recycle and reuse water
  of wastewater from sinks,
  kitchens,tubs, washing machines,
  and dishwaters
  for landscaping, flushing toilets, etc.;
- Waterless technologies, e.g., composting
  toilets, waterless urinals;
- Rain harvesting (rain barrels, cisterns)



Source: EPA Office of Water, 2008

# Integrate Practices on Neighborhood Scale

- Jordan Cove, Connecticut , monitored for10 years: 17 traditional lots; 12 green infrastructure lots;

  swales, bioretention (rain gardens), pervious pavements

- High Point, Seattle: [www.thehighpoint.com](www.thehighpoint.com), replaces 716 dilapidated public housing units with 1600 units on 120 acres; large income range;

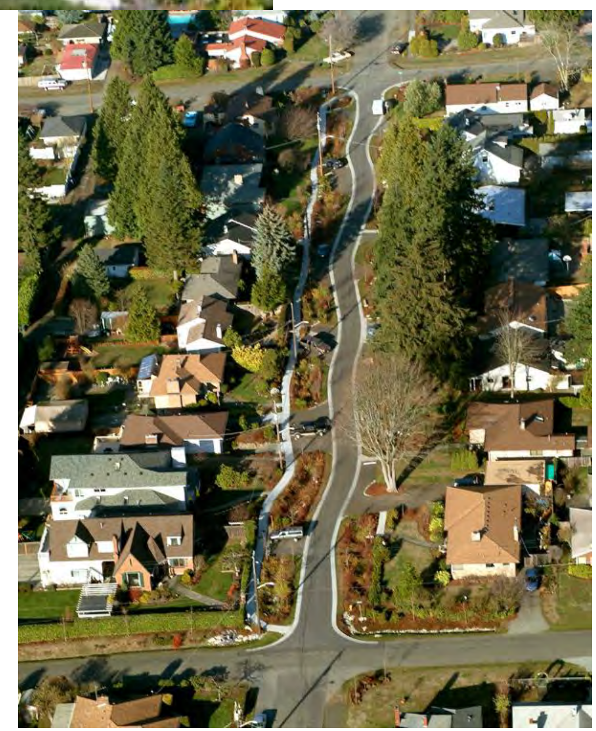
  swales, porous pavement, gravel, rain gardens, landscaped shaped for absorption, detention pond down-slope for "rare events"



Source: EPA Office of Water, 2008

# Seattle Street Edge Alternative (SEA) Street Project

- Reduced impervious surfaces to 11% less than traditional street
- Surface detention swales
- 100 evergreen trees
- 1100 shrubs
- Volume of stormwater discharge reduced 99%

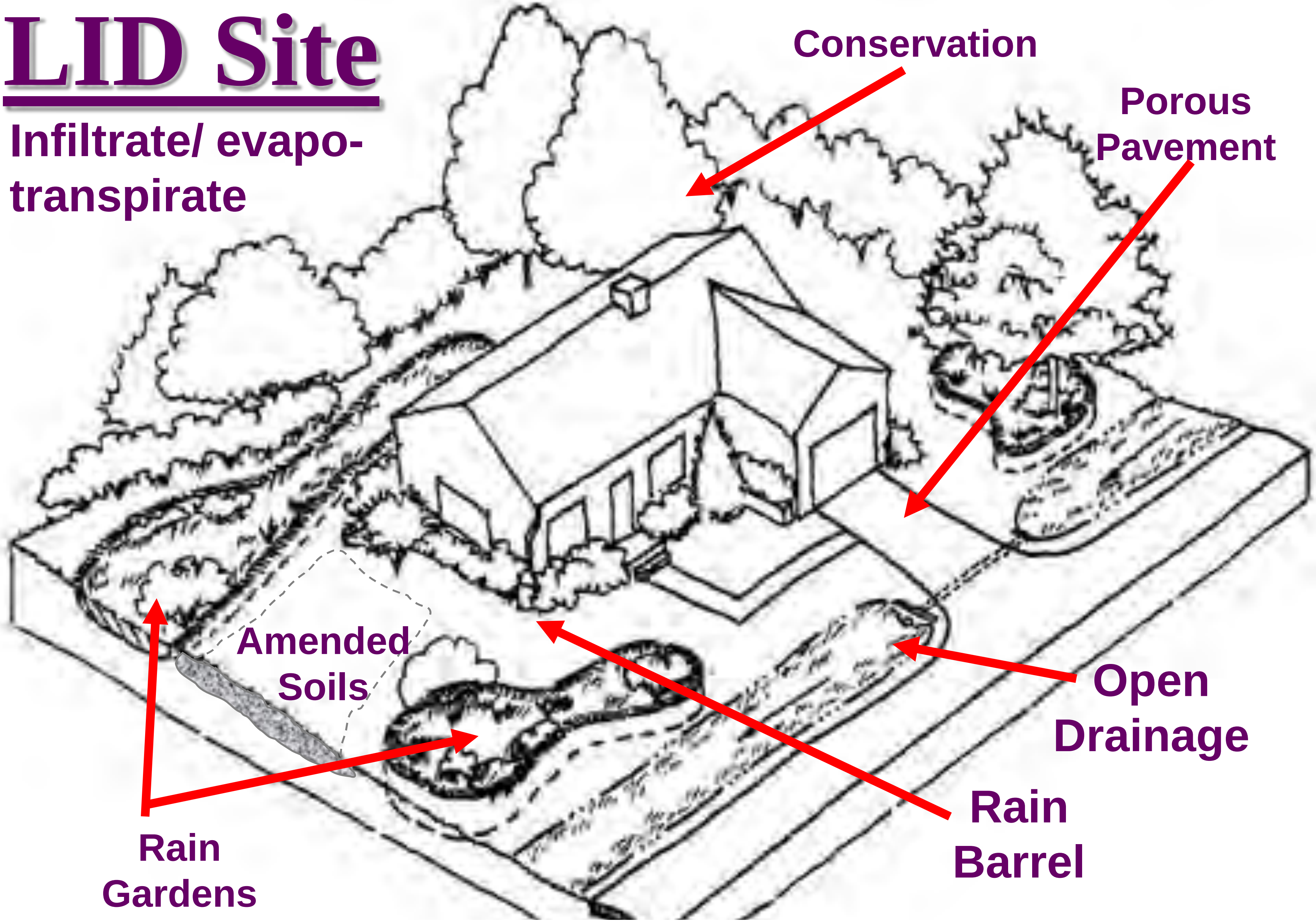




Source: EPA Office of Water, 2008

# LID Site

Infiltrate/ evapo-transpirate




Source: EPA Office of Water, 2008

# Cost Comparisons

**Table 2. Summary of Cost Comparisons Between Conventional and LID Approaches[a]**

| Project | Conventional Development Cost | LID Cost | Cost Difference[b] | Percent Difference[b] |
|---|---|---|---|---|
| 2nd Avenue SEA Street | $868,803 | $651,548 | $217,255 | 25% |
| Auburn Hills | $2,360,385 | $1,598,989 | $761,396 | 32% |
| Bellingham City Hall | $27,600 | $5,600 | $22,000 | 80% |
| Bellingham Bloedel Donovan Park | $52,800 | $12,800 | $40,000 | 76% |
| Gap Creek | $4,620,600 | $3,942,100 | $678,500 | 15% |
| Garden Valley | $324,400 | $260,700 | $63,700 | 20% |
| Kensington Estates | $765,700 | $1,502,900 | –$737,200 | -96% |
| Laurel Springs | $1,654,021 | $1,149,552 | $504,469 | 30% |
| Mill Creek[c] | $12,510 | $9,099 | $3,411 | 27% |
| Prairie Glen | $1,004,848 | $599,536 | $405,312 | 40% |
| Somerset | $2,456,843 | $1,671,461 | $785,382 | 32% |
| Tellabs Corporate Campus | $3,162,160 | $2,700,650 | $461,510 | 15% |

[a] The Central Park Commercial Redesigns, Crown Street, Poplar Street Apartments, Prairie Crossing, Portland Downspout Disconnection, and Toronto Green Roofs study results do not lend themselves to display in the format of this table.

[b] Negative values denote increased cost for the LID design over conventional development costs.

[c] Mill Creek costs are reported on a per-lot basis.

Reducing Stormwater Costs through LID Strategies and Practices, EPA 2007

# LID is a System

- LID is a set of BMP's that are tailored to collectively achieve the runoff-reduction objective.
- E.g., (1) Disconnect downspouts, (2) store some runoff in a barrel or cistern, (3) infiltrate the remainder into a rain garden, & (4) use pervious asphalt in the driveway.



Source: EPA Office of Water, 2008


Conventional
Low Impact
'96 6 4
Conventional
Functional Landscape Design

# Energy Independence & Security Act of 2007

**"Sec. 438. Storm Water Runoff Requirements for Federal Development Projects:**
The sponsor of any development or redevelopment project involving a Federal facility with a footprint that exceeds 5,000 square feet shall use site planning, design, construction, and maintenance strategies for the property to maintain or restore, to the maximum extent technically feasible, the predevelopment hydrology of the property with regard to the temperature, rate, volume, and duration of flow."

# Clean Water Act Sec. 101

- **Chemical impairment** – sediment; low dissolved Oxygen; additional problems include temperature and nutrients
- **Physical impairment** – streambank erodes; bed fills with silt, and
- **Biological impairment** – depleted fish and macro-invertebrate populations; the habitat for spawning is compromised or absent
- Not **Fishable** – no fish!
- Not **Swimmable**– very low flow except when raining



Source: EPA Office of Water, 2008

# Rain Gardens


# Scuppers into Stormwater Planter

Source: EPA Office of Water, 2008

Source: EPA Office of Water, 2008

Source: EPA Office of Water, 2008



Source: EPA Office of Water, 2008

# Cost-Saving Example

## Pembroke Woods (Frederick County, MD)

- Eliminated curbs, gutters, sidewalks, 2 ponds.
- Narrower streets reduced imperviousness and reduced paving costs by 17 percent.
- Eliminating 2 SW ponds saved $200K and added space for 2 developable lots ($45K each).
- Saved $160K of land clearing costs; & added 2.5 acres of open space, reducing 404 mitigation.



Source: EPA Office of Water, 2008

# LID Cost-saving Ideas

- Disconnecting downspouts rapidly saved money for Flint, MI's SW/CSO programs:
  - Reduced flows across all precipitation events by 26%
  - cost recovered in 2 months.

- Portland is funding a huge downspout disconnection program (reducing CSO's by 4.2M cu. m. (=1 billion gallons) annually.

  Portland's CSO Program Progress Report, 2006

- Combine street-edge programs with street traffic-calming programs (e.g., Portland).



Source: EPA Office of Water, 2008

"We've got to do things smarter throughout the Air Force. And this is one of those simple ways that we can conserve energy and save money."
Randy Hawke, Facilities Excellence Architect

Equipment is unloaded to construct a green roof at Peterson Air Force Base. (USAF, Steve Brady)





Source: EPA Office of Water, 2008

# What are Benefits of LID?

- Positive impacts on stream hydrology and streambank structure
- Reduce pollutant discharge
- Connect to floodplain and reduce flooding
- Increased groundwater recharge
- Reduce energy consumption
- Reduced urban heat island impacts



Source: EPA Office of Water, 2008

# Benefits of LID

- Aesthetics -- rain gardens and green roofs add beauty --
- Enhance property values
- Community benefits from green space
- Trees and green roofs benefit air quality by sequestering pollutants
- Green roofs last longer than traditional roofs, conserve natural resources



Source: EPA Office of Water, 2008

# The Way Ahead from here…

- DoD is participating with EPA / Office of Water to develop flexible and site-specific technical Section 438 guidance on green infrastructure tools, practices, and approaches;
- EPA's Green Infrastructure "Strategy" has 7 categories: Research; Outreach & Communication; Tools; CWA Regulatory Support; Economic Viability & Funding; Demonstrations & Recognition; and Partnerships;
- Key Priority:  Assembling and organizing data on LID effectiveness, costs, cost savings, and benefits to society and the environment.
- EPA is developing a library of good model ordinances as develop good info on model permit language for MS4 permits. We're providing tech assistance to several States.



Source: EPA Office of Water, 2008

# Conclusion

- LID is not rocket science; runoff volume reduction can be estimated within reasonable range for rain barrels, cisterns, rain gardens, porous pavements, green roofs, trees, and for general reduction of impervious surfaces;
- A rapidly increasing pool of experience is verifying that LID works and is affordable;
- Sustainable development offers the opportunity to treat water as a resource – offering community benefits –



Source: EPA Office of Water, 2008

# Resources

The Center for Watershed Protection website: http://www.cwp.org/

Low Impact Development Center: www.lowimpactdevelopment.org

LEED-ND Website's Stormwater Provision: www.usgbc.org/ShowFile.aspx?DocumentID=2845, p. 115-17

EPA's Green Infrastructure website: www.epa.gov/npdes/greeninfrastructure

EPA's NPS and LID Websites: www.epa.gov/nps and www.epa.gov/nps/lid

An excellent commercial green roof website: www.greenroofs.com

Wisconsin DNR Rain Garden Manual www.dnr.state.wi.us/org/water/wm/nps/rg/index.htm

WERF Stormwater Whole Life Cost Model

# More Resources

"The Economics of Low Impact Development: A Literature Review"

www.muddywaterwatch.org/images/Economics_of_LID.pdf

"Green Values Stormwater Toolbox" LID Calculator

http://greenvalues.cnt.org

"Sustainable Raindrops", by Hudson Riverkeeper

http://www.riverkeeper.org/campaign.php/pollution/the_facts/986

"Reducing Stormwater Costs through LID Strategies and Practices"

www.epa.gov/nps/lid

"Better Site Design", by Center for Watershed Protection

www.cwp.org

Abby Hall's LID Slides (currently includes 391 slides from 11 cities)

http://picasaweb.google.com/buildgreeninfrastructure

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